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DEPARTMENT OF COMMERCE - BUREAU OF MINES

SAFEGUARDING ELECTRICAL EQUIPMENT USED IN GASSY MINES[1]

EUROPEAN PRACTICE: I - GREAT BRITAIN

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INTRODUCTION

Cooperation between the United States Bureau of Mines and the Safety in Mines Research Board of Great Britain, continuous since 1924, has made possible this and other papers on safety subjects. Grateful acknowledgment is made to representatives of the Safety in Mines Research Board of the Mines Department for their assistance in arranging visits to several mine safety stations, and to F. H. Wynne, Deputy, Chief Inspector of Mines, Great Britain, for arranging visits to mines in Great Britain, Belgium, France, and Germany.

During the summer of 1927 the writer had the privilege of visiting the mine safety testing stations in Great Britain, Belgium, Germany, and France, in the order named. All of these countries have large coal mines, many of which are rated as gassy. Therefore, when the installation of electrical equipment is contemplated, each of these countries is confronted with the same safety problem as in the United States - the development of electrical equipment that will not ignite gassy mine atmospheres, should such atmospheres through neglect or accident surround the equipment. The means used by those countries in safeguarding gassy mines should therefore be of general interest to safety engineers in American coal mines, and it is proposed to give a brief survey for each of the four countries mentioned. The first of these surveys will cover conditions in Great Britain.

REGULATION BEARING ON SAFETY

A good beginning may be made by mentioning some of the requirements found in "Coal Mines Act, 1911." This act includes a section, "General Regulations As to the Installation and Use of Electricity," from which the following pertinent paragraphs have been abstracted:

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1 - The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)

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(119.) Notices shall be sent to the Inspector of the Division, on the forms prescribed by the Board of Trade, as follows, namely:

(119.)--(i.) Notice of the intention to introduce apparatus into any mine, or into any ventilating district in any mine.

If the Inspector of the Division does not object in writing, within one calendar month from the receipt by him of the notice, to the carrying out of either of the intentions specified in the first or second notices, the owner shall be entitled to carry out such intention or intentions.

Provided that this regulation shall not apply to telephones and signalling apparatus.

(119.)--(ii.) Notice of the intention to introduce or reintroduce electrocity into any mine where the use of electricity has previously been prohibited by Section 60 (1) of the Act.

If the Inspector of the Division does not object in writing, within one calendar month from the receipt by him of the notice, to the carrying out of either of the intentions specified in the first or second notices, the owner shall be entitled to carry out such intention or intentions.

Provided that this regulation shall not apply to telephones and signalling apparatus.

(119.)--(iii.) On or before the 21st day of January in every year an annual return giving the size and type of appratus and any particulars which may be required by the Board of Trade as to the circumstances of its use.

(125.)--(a.) All metallic sheaths, coverings, handles, joint-boxes, switchgear frames, instrument covers, switch and fuse covers and boxes, and all lampholders, unless efficiently protected by an earthed or insulating covering made of fire-resisting material, and the frames and bedplates of generators, transformers, and motors (including portable motors), shall be earthed by connection to an earthing system at the surface of the mine.

This rule shall not apply (except in the case of portable apparatus) to any system in which the pressure does not exceed low-pressure direct current or 125 volts alternating current.

(125.)--(b.) Where the cables are provided with a metallic covering constructed and installed in accordance with Regulation 129 (e) such metallic covering may be used as a means of connection to the earthing system. All the conductors of an earthing system shall have a conductivity at all parts and at all joints at least equal to 50 per cent of that of the largest conductor used solely to supply the apparatus a part of which it is desired to earth. Provided that no conductor of an eathing system shall have a cross-sectional area of less than 0.022 of a square inch.

(125.)--(c.) All joints in earth conductors and all joints to the metallic covering of the cables shall be properly soldered or otherwise efficiently made, and every earth conductor shall be soldered into a lug for each of its terminal connections. No switch, fuse, or circuit breaker shall be placed in any earth conductor.

(131.)--(a.) Every person appointed to work, supervise, examine, or adjust any apparatus shall be competent for the work that he is set to do. No person except an electrician or a competent person acting under his supervision shall undertake any work where technical knowledge or experience is required in order adequately to avoid danger.

(131.)--(b.) An electrician shall be appointed in writing by the manager to supervise the apparatus. If necessary for the proper fulfillment of the duties detailed in the succeeding paragraphs of this rule, the manager shall also appoint in writing an assistant or assistants to the electrician.

(131.)--(c.) The electrician shall be in daily attendance at the mine. He shall be responsible for the fulfillment of the following duties, which shall be carried out by him or by an assistant or assistants duly appointed under paragraph (b) : (i.) the thorough examination of all apparatus (including the testing of earth conductors and metallic coverings for continuity) as often as may be necessary to prevent danger; and (ii) the examination and testing of all new apparatus, and of all apparatus reerected in a new position in the mine before it is put into service in the new position.

Provided that in the absence of the electrician for more than one day the manager shall appoint in writing an efficient substitute.

(131.)--(d.) The electrician shall keep at the mine a log book made up of daily log sheets kept in the form prescribed by the Secretary of State. The said log book shall be produced at any time to an inspector of mines on his request.

(131.)--(e.) Should there be a fault in any circuit the part affected shall be made dead without delay, and shall remain so until the fault has been remedied.

(131.)--(f.) All apparatus shall be kept clear of obstruction and free from dust, dirt, and moisture, as may be necessary to prevent danger.

Inflammable or explosive material shall not be stored in any room, compartment, or box containing apparatus, or in the vicinity of apparatus.

(131.)--(g.) Adequate precautions shall be taken by earthing or other suitable means to discharge electrically any conductor or apparatus, or any adjacent apparatus, if there is danger therefrom, before it is handled, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon. While lamps are being changed the pressure shall be cut off.

Provided that this paragraph shall not apply to the cleaning of commutators and slip rings working at low or medium pressures.

(131.)--(h.) The person authorized to work an electrically-driven coal-cutter or other portable machine shall not leave the machine while it is working, and shall, before leaving the working place, ensure that the pressure is cut off from the flexible trailing cable which supplies such coal-cutter or other portable machine. Trailing cables shall not be dragged along by the machine when working.

(131.)--(i.) Every flexible cable shall be examined periodically (if used with a portable machine, at least once in each shift by the person authorized to work the machine), and if found damaged or defective it shall forthwith be replaced by a spare cable in good and substantial repair. Such damaged or defective cable shall not be further used underground until after it has been sent to the surface and there properly repaired.

(132.) In any part of a mine in which inflammable gas, although not normally present, is likely to occur in quantity sufficient to be indicative of danger, the following additional requirements shall be observed:-

(132.)--(i.) All cables, apparatus, signalling wires, and signalling instruments, shall be constructed, installed, protected, worked, and maintained, so that in the normal working thereof there shall be no risk of open sparking.

(132.)--(ii.) All motors shall be constructed so that when any part is live all rubbing contacts (such as commutators and slip-rings) are so arranged or enclosed as to prevent open sparking.

(132.)--(iii.) The pressure shall be switched off apparatus forthwith if open sparking occurs, and during the whole time that examination or adjustment disclosing parts liable to open sparking is being made. The pressure shall not be switched on again until the apparatus has been examined by the electrician or one of his duly appointed assistants, and the defect (if any) has been remedied or the adjustment made.

Some of the outstanding features of the rules just quoted that have a chief bearing in maintaining electrical safety are:

1. Strict rules with respect to giving notice to the Mines Department of intention of installing new equipment.

2. Strict rules regarding the earthing (grounding) of all equipment and wiring.

3. Instructions for selection of the electrician and other workmen with the requirement that the electrician must be in constant attendance.

4. Requirement that a daily log must be kept of happenings on electrical apparatus in a prescribed log book.

5. Requirement that defective equipment be put out of service at once.

6. Special rules covering the use of electrical equipment and wiring in gassy portions of the mine to prevent "open sparking."

TESTS AND REQUIREMENTS FOR ELECTRIC MOTORS

The users and manufacturers of electrical equipment are taking forward steps to formulate testing procedure for equipment and to meet the expense entailed in having types of equipment tested.

The following regulation approved and issued in 1926 under the auspices of the British Engineering Standards Association (composed of the Institution of Civil Engineers, Institution of Mechanical Engineers, Institution of Naval Architects, Iron and Steel Institute, and Institution of Electrical Engineers) shows the general trend of testing electrical equipment for safety in Great Britain:

British Standard Specifications for Flame-Proof Enclosures and for Testing Such Enclosures

I. Definition of Flame-Proof Enclosure (Including Explosion-Proof) for Electrical Apparatus.

1. A flame-proof enclosure (including explosions-proof) for electrical apparatus is one which will withstand, without injury, any explosion that may occur in practice within it under the conditions of operation within the rating of the apparatus enclosed by it (and recognised overloads, if any, associated therewith), and will prevent the transmission of flame such as will ignite any inflammable mixture which may be present in the surrounding atmosphere.

Note 1.--In the absence of any statement to the contrary, it is assumed that the flame-proof enclosure has to meet the ordinary requirements of the Coal Mining Industry in which the inflammable mixture to be considered will ordinarily contain methane, but in other industries other inflammable mixtures will be encountered. Similarly it will be necessary to consider other inflammable gases in relation to particular apparatus, such as the gas resulting from decomposed oil in oil-immersed switchgear and hydrogen in storage batteries.

Note 2.--In view of the danger which would result from a destructive short-circuit within the enclosure, special attention to details of deisgn and manufacture is necessary. In addition, the protection of the circuit supplying the apparatus should be such as to ensure, as far as practicable, that the highest recognised overload for the apparatus shall not be exceeded, having regard to the amount of destructive energy available at the apparatus calculated from the size of generating plant and the impedance of the circuit between it and the apparatus.

II. Specification of Tests for Various Classes of Apparatus to Prove Compliance with the Definition of Flame-Proof Enclosure.

General

2. In conformity with Note 1 to the Definition of Flame-Proof Enclosure, it is assumed that the apparatus has to meet the ordinary requirements of the Coal Mining Industry in which the inflammable mixture to be considered will ordinarily contain methane.

For some purposes a certificate may be required as to the flame-proof qualities of a casing with respect to such inflammable mixtures as, for example, hydrogen and air. Such a certificate shall be granted only on the results of tests carried out with the particular inflammable gas specified therein.

The design and construction of flame-proof apparatus submitted for test and certificate should comply, as regards flame-proof enclosure, with the B.E.S.A. Specification, if any exists, for such apparatus, but if there is no such Specification then the principles of design and construction, as regards flame-proof enclosure, in any appropriate B.E.S.A. Specification should be observed.

Tests

3. The following tests shall be carried out with the apparatus correctly assembled, with all its parts (including oil, filling compounds, etc., if any) in place, and with all electrical connections from the interior to the exterior of the casing made. Apparatus designed for the protection of rapidly revolving parts, such as a motor casing, shall be tested with such parts running at their maximum working speed.

To meet the ordinary requirements of the coal mining industry, the casing shall be filled at the air temperature and pressure prevailing at the testing station with the most explosive mixture of methane and air (i.e., containing between 9.5 and 10.5 per cent of methane by volume) and shall be surrounded by the most readily ignited mixture of methane and air (i.e., containing between 8.5 and

10.5 per cent of methane by volume) at the air temperature and pressure prevailing at the testing station. The tests of flame-proof enclosures in any other inflammable atmosphere than that containing fire damp shall be made with the most explosive mixture of the particular inflammable gas and air at the temperature and pressure prevailing at the testing station. The explosive mixture within the casing shall be ignited, if possible, by the spark produced when an electric current of sufficient intensity is established or broken by the normal mechanical operation of the apparatus. Otherwise, any suitable means may be employed provided that the position of the point of ignition would be produced in the normal working of the apparatus.

It is recognised that until such time as experimental work on the testing of switchgear under short circuit conditions has been completed, it would be unwise to specify that the enclosure should be tested for its flame-proof properties with the apparatus operating under the most severe conditions likely to be met in normal service. The tests specified, therefore, are liable to revision and modification after further research if it is found that testing under short-circuit conditions is essential.

Note:--It is not considered desirable to define the number of tests or the character of any additional tests which the testing officer might desire to make. It is hoped that further instructions can be given after experience has been gained.

Test Certificate

4. An apparatus that satisfies the requirements of this Specification and has passed the tests to which it has been submitted can be considered as complying with the British Standard definition of Flame-Proof Enclosure and a certificate in the form given in Clause 5 should be granted.

Form of Test Certificate

5. The following form of test certificate should be used:---

Certificate of Test as to Flame-proof Enclosure. This is to certify that a .... (description of article), identical in all essential respects as to design, workmanship and material with that indicated on Drawing No. .... has been submitted by .... (Name of Maker) for test to prove compliance with the definition of flame-proof enclosure (B.E.S.A. Publication No. 229--1926.) and has been found to satisfy the requirements in all respects, A full report of the tests carried out has been furnished to the maker.

Signed..................(testing authority).

Date.................

Type Tests

6. It is not intended, nor is it recommended, that the tests referred to above shall be made on every piece of apparatus supplied.

Unless otherwise specified when inviting tenders, the purchaser shall accept, as evidence of compliance of the apparatus with this Specification, type tests on apparatus identical in all essential details with the one purchased.

Certificates and full report of all type tests with certified detailed drawings of the type apparatus shall be held available by the maker, together with a record of any alterations, whether essential or not, which have been made to the apparatus since any type test was carried out.

Type tests shall be made by a recognised authority.

Twenty-five Government Departments and Scientific and Industrial Organisations were officially represented upon the Committees entrusted with the preparation of the Specification.

TESTING OF FLAME-PROOF EQUIPMENT

Although the Mines Department tests flame safety lamps, electric lamps, signals, telephones, and shot-firing equipment, it does not test electric motors and their accessories. Such tests as are made are either conducted by the manufacturers of the equipment or are arranged for by them.

The University of Sheffield has an agreement with the manufacturers whereby tests are made of flame-proof equipment at Sheffield. These tests, although generally witnessed by an engineer from the Mines Department, can not be said to be officially endorsed by that department. Equipment that satisfies the conditions laid down for the tests is given a certificate by the University.

The writer witnessed some of the testing work at Sheffield and was deeply interested in it because similar testing work was being done at the Pittsburgh Experiment Station of the U. S. Bureau of Mines.

The test procedure at Sheffield is as follows:

The submittor of the equipment is required to furnish blue-print copies of drawings showing the general construction of the apparatus submitted. These prints are consulted in deciding whether or not the construction of the apparatus is satisfactory and are further used in checking the dimensions of the various parts making up the equipment. Prints are held on file as a part of the permanent record of the test.

The tests are made in a wooden gallery. The gas used for the explosive mixture is methane, which is obtained from a mine and kept in cylinders. An explosive mixture is kept ready mixed in a large container for certain of the tests. In the case of a motor the first test is made by filling the motor with an explosive mixture of methane and igniting the mixture. During this test one end of the gallery is open. This test is made without an explosive mixture surrounding the motor and is for the purpose of observing whether flames come through any of the flanges or the other joints. After the completion of this test, the front of the gallery is put in place and five additional tests are made with the motor surrounded with an explosive mixture of methane and air. Two of the tests are with the motor at rest and three tests with the motor running. Owing to the construction of the gallery the motor is not under observation in any of the tests in which the motor is surrounded by the explosive mixture. The evidence of safety is therefore based upon the one test made at the beginning under observation and the fact that in the additional five tests the gas was not exploded or the compartment blown apart. Pressure records and analyses of gas samples are obtained for all the explosion tests. The proper proportion of the mixture surrounding the motor is judged by exploding samples drawn from the gallery during the mixing of the methane and air. The methane is slowly admitted from one of the tanks and mixed with a fan as it enters.

The gallery is provided with a partition to conserve the amount of gas necessary for producing an explosive mixture. If the apparatus is small enough it is installed in a half section of the gallery.

A typical certificate follows:

University of Sheffield

MINING DEPARTMENT,
UNIVERSITY OF SHEFFIELD,
ST GEORGE'S SQUARE,
SHEFFIELD

(SEAL)

Telephone 4705

October 15th., 1923.

Certificate No. 40.

This is to certify that a typical example of MESSRS. THE ELECTRO-MECHANICAL BRAKE COMPANY, LIMITED, MINING TYPE FLAME PROOF CONTROLLER TYPE 50A., 30. HP., has been treated as follows:-

> The casing of the controller was filled with the most explosive mixture of fire damp and air, and this mixture was ignited by a secondary discharge from an induction coil, whilst the apparatus assembled as for use was surrounded by a similar explosive mixture.

Under these conditions of test, flame did not pass from the apparatus to the explosive atmosphere outside, which remained unignited, nor did the apparatus suffer damage due to the pressure developed within it.

Signed: D. Hay

Professor of Mining.

When one considers the rigid regulations covering electrical equipment in British mines, it would be natural to think that the protective requirements for gassy parts of a mine would be especially severe, but this is not necessarily the case. Much of the equipment used at the face workings has not been tested at Sheffield. The tendency apparently is to place more emphasis on inspection than on actual tests in gaseous mixtures. The Bureau of Mines has found in testing a great many outfits representing the product of several manufacturers that tests are very valuable in showing unsuspected weaknesses of equipment which might easily be overlooked or not evident from an inspection.

RESEARCH WORK BY THE SAFETY IN MINES RESEARCH BOARD

During a period of several years a systematic study has been made by the Safety in Mines Research Board, under R. V. Wheeler, of fundamentals that may have a direct or indirect bearing on the design of permissible electrical accessories for motor-operated outfits; the following reports have been issued:

1. Flame-Proof Electrical Apparatus for use in Coal Mines, by I. C. E. Statham and R. V. Wheeler, Paper No. 5, First Report, Flange Protection, 1924.

2. Flame-Proof Electrical Apparatus for use in Coal Mines, by C. S. W. Grice, and R. V. Wheeler, Paper No. 21, Second Report, Perforated Protection, 1926.

3. Flame-Proof Electrical Apparatus for Use in Coal Mines, by H. Rainsford and R. V. Wheeler, Paper No. 35, Third Report, Ring-Relief Protection, 1927.

4. The Pressures Produced on Blowing Electric Fuses, by G. Allsop and R. V. Wheeler, Paper No. 38, 1927.

The writer saw most of the equipment used in conducting these researches and conferred with several of the investigators who had been connected with the work. It may be mentioned here that these researches cover work for which the United States Bureau of Mines has never had sufficient personnel, and as the work has been done in a thorough manner it will probably never be necessary for the Bureau to undertake it.

ELECTRICAL INSPECTION

The electrical inspection work in Great Britain is in the hands of the Divisional, Assistant, and Junior Mine Inspectors; in case of an electrical accident or a difficult electrical problem, these men call on the Chief Electrical Inspector, who has his headquarters at the Main Office of the Mines Department.

The inspection of electrical equipment is made comparatively easy by the rigid rules (samples of which have already been given) governing the installation of new equipments and the maintenance requirements for all electrical equipment.

There is only one electrical inspector, and as his is a huge task it is impossible to avoid some mistakes and misjudgments in permitting installations. Greater safety would undoubtedly result if more electrical equipment was subjected to actual tests in gas.

In addition to the Government inspection, many of the owners carry out very complete and systematic periodic inspections. One company with four collieries had a force of 16 electricians and a most elaborate inspection system.

ELECTRICAL EQUIPMENTS IN GREAT BRITAIN AND THE UNITED STATES CONTRASTED

There are a number of differences between the electrical installations in Great Britain and the United States. For instance, in British coal mines there are no trolley locomotives, whereas statistics compiled for 1924 give 11,986 in the United States. Every piece of apparatus and practically every conductor in British mines is earthed by carrying a ground conductor to a ground plate on the surface; practically no earthing is resorted to in American mines except to connect the frames of stationary motors to a pipe or rail return within the mine. Alternating current is not used extensively in American mines, but in British mines this prevails, and direct-current circuits are being replaced by alternating-current circuits in a number of mines. The natural conditions in British mines as to grades, faults, thinness of seams, extreme depth of shafts, and the difficulty of properly supporting the overburden render the installation of electrical equipment much more difficult than in American mines.

In regard to electrical safety it can be said without danger of contradiction that the regulations governing the installation, inspection, and maintenance of electrical equipment are better in Great Britain than in America. In regard to the practice of using strictly safe equipment in gassy sections of mines, there is much yet to be done in both countries.

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